

## **Invited talk**

Special Session on Ultrasonic Sensors and Motors  
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### **Ultrasonic Motors (USM) -- an Emerging Actuation Technology for Planetary Applications**

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## **ABSTRACT**

Efficient miniature actuators that are light, compact and driven by low power are needed to drive telerobotic devices and space mechanisms in future NASA missions. Examples of space mechanisms and devices that require actuators include robotic arms, miniature rovers, release mechanisms, positioning devices, aperture opening and closing devices, and real-time compensation for thermal expansion in space structures, etc. These motors need to operate at various temperatures and pressures with a large range of thermal variations over a relatively short period swing. Ultrasonic rotary motors have the potential to meet this NASA need and they were developed as actuators for miniature telerobotic applications. These motors were adapted for operation at the environment of Mars that include very low temperatures and vacuum and analytical tools were developed for the design of efficient motors. A hybrid analytical model was developed to address a complete ultrasonic motor as a system. Included in this model is the influence of the rotor dynamics, which was determined experimentally to be important to the motor performance. The analysis employs a 3D finite element model to express the dynamic characteristics of the stator with piezoelectric elements and the rotor. The details of the stator including the teeth, piezoelectric ceramic, geometry, bonding layer, etc. are included to support practical USM designs. A brush model was used for the interface layer and Coulomb's law for the friction between the stator and the rotor. The theoretical predictions were corroborated experimentally for the motor. In parallel, efforts have been made to determine the thermal and vacuum performance of these motors and effective operation at temperatures as low as  $-150^{\circ}\text{C}$  and a pressure of 16-mtorr were demonstrated. To explore telerobotic applications for USMs a robotic arm was constructed with such motors.

**Key Words:** Actuators, Piezoelectric Motors, Active Materials, Ultrasonic Motors, Stators and Rotors, Modal Analysis